Chapter 2
General Design Considerations

2-1. General

This chapter provides general considerations for selecting the appropriate channel type and defining the requirements for executing the selected design.

2-2. Selection of Channel Type

Paragraph 1-6 identifies the hydraulic capacity as the primary functional consideration and the costs of right-of-way, relocations, construction, and operation as economic considerations for selecting channel type. Existing site developments, existing geophysical site conditions, and performance or service requirements impact the selection of channel type and the resulting construction costs. The construction cost of trapezoidal channel sections is less than that of rectangular sections. Generally, the lowest cost of erosion protection is sod, and the cost increases with riprap protection and even more when reinforced concrete paving is used. Typical trapezoidal channel types are shown in Figure 2-1.

a. Existing site developments. Existing roads, bridges, and buildings in highly developed areas often dictate the channel type and channel configuration. The more expensive rectangular channel sections, discussed in Chapters 4 and 5, are commonly required in areas where the right-of-way is highly restricted. Typical rectangular channel types are shown in Figure 2-2.

b. Geophysical site conditions. Existing geophysical site conditions including the characteristics of in situ materials, depth of frost penetration, ground water levels, subsidence potential, faulting, and earthquake potential impact design solutions. The strength and erodability of in situ materials usually dictate whether a channel lining is required. Reinforced concrete walls located in seismic zones should be designed and constructed to resist the earthquake forces. High ground water levels increase the requirements for subdrainage systems.

c. Service requirements.

(1) Top of channel. The project's level of protection is selected by a comparison of hydraulic flow line calculations, construction costs for various channel sizes, and economic benefits. These calculations are based on risk and uncertainty principles. The selected level of protection will define the nominal elevation of the top of the channel. This elevation may be modified locally to account for flow disturbances from causes such as bridge piers, side channels, or channel bends.

(2) Channel flow. Channel flow patterns and changes in the water surface at bends in the channel should be considered in determining the channel cross section and overall configuration requirements.

(a) Pilot channels. Pilot channels are constructed in the bottom of flat bottom channels which carry low flows except during floods. These channels confine low flows thereby maintaining higher velocities which may decrease the amount of sediment and trash deposits. The success of pilot channels has been varied. Experience has shown that sediment deposits occur in a pilot channel when the channel slope is not sufficient to maintain the velocities required to transport the sediments. An alternate design to a pilot channel is a V-shaped channel bottom. These channel configurations are shown in Figure 2-1.

(b) Channel linings. Channel lining requirements are dependent upon the maximum velocity of flows and the resistance of the in situ materials to erosion. The quality of contained waters may affect the design of concrete linings. The presence of salts, sulfates, industrial wastes, and other abrasive or scouring materials sometimes requires thicker concrete lining sections with increased reinforcement cover. Mix design revisions using appropriate admixtures should be considered as an alternative to increasing the lining thickness.

(c) Supplementary structures. Supplementary or appurtenant structures such as weirs, tunnels, culverts, inverted siphons and chutes, sediment or debris basins, and drop structures are often required. These appurtenant features are designed to satisfy the channel flow conditions.

(d) Terminal structures. When the downstream end of a channel lining project terminates in erodible material, some type of energy dissipation treatment, such as stilling basin, drop structure, or riprap, is needed.

2-3. Reinforced Concrete Structures

a. Materials. Materials for the construction of the reinforced concrete structures of concrete lined flood control channels shall comply with current Corps of Engineers guide specifications.

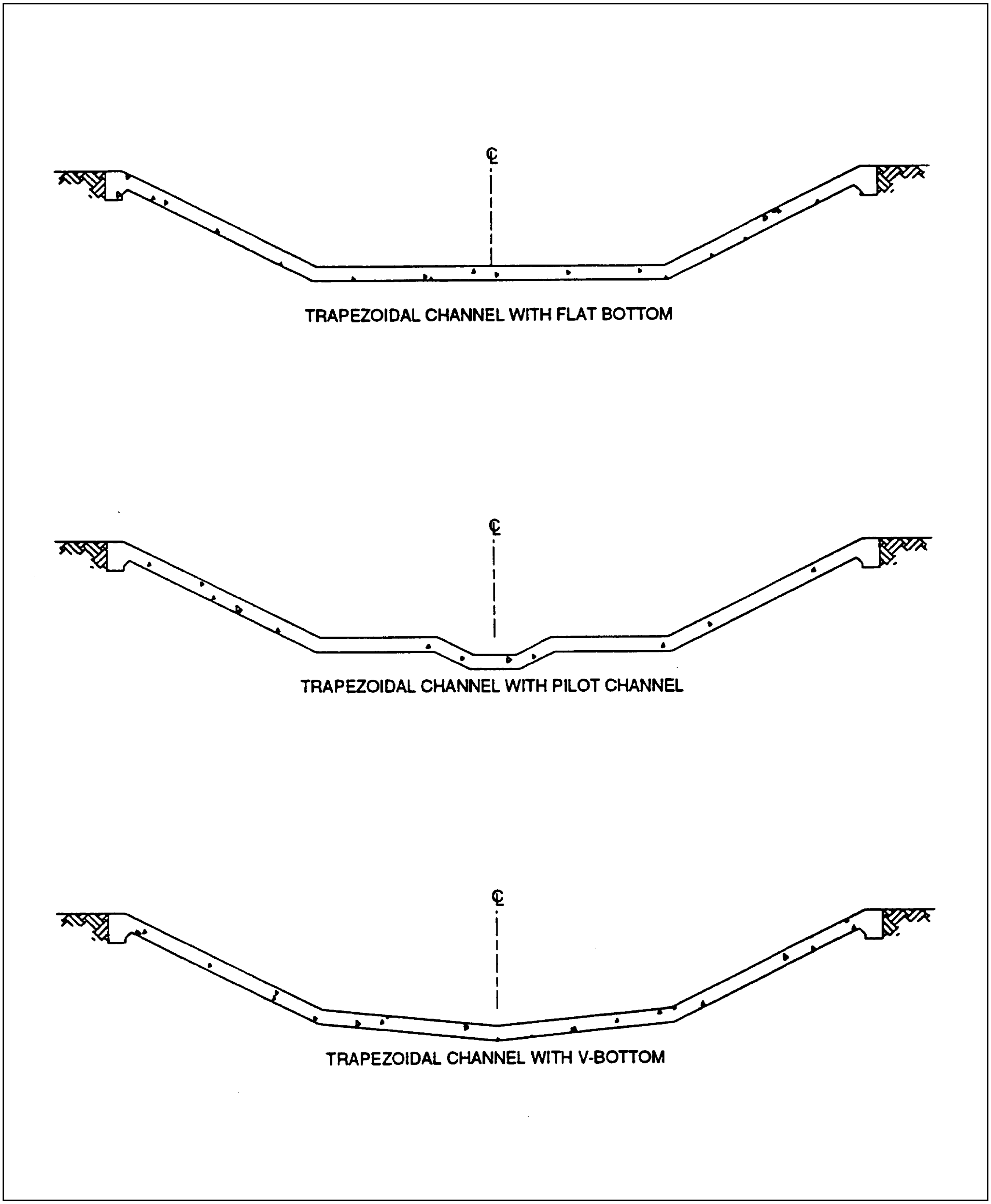

Figure 2-1. Trapezoidal channel sections

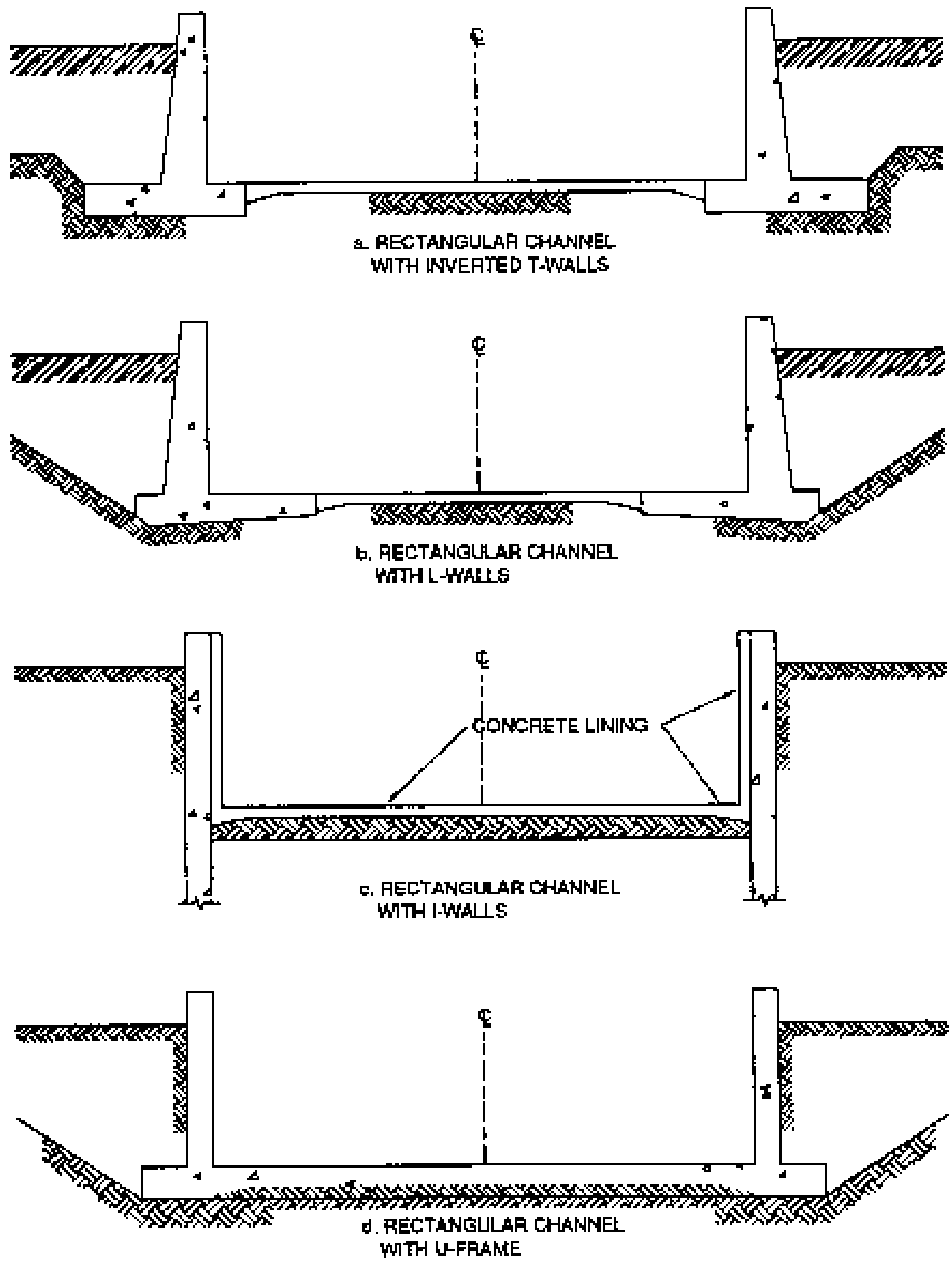

Figure 2-2. Rectangular channel sections

(1) Concrete. Guidance for concrete materials and mixture proportioning is given in EM 1110-2-2000. Typically, a compressive strength of 25 MPa (3,000 psi) at 28 days is used. Higher strengths may sometimes be justified for retaining walls, I-walls, or U-frame structures. Air-entrained concrete should be used when freeze-thaw conditions are anticipated. Microsilica, fly ash, aggregate hardness, etc., should be considered as improvements in resistance to abrasion, when required. Type II cement should be used when sulfates are present in moderate concentration.

(2) Reinforcement. Steel bars shall be American Society for Testing and Materials (ASTM) Grade 60, deformed, cut lengths, or fabricated mats. Steel welded wire fabric shall be deformed wire produced from rods or bars that have been hot rolled. Consideration should be given to the use of a lower-permeability concrete and epoxy coated or galvanized reinforcement steel in areas where channel linings will be subjected to highly corrosive constituents such as saltwater or sanitary and industrial wastes.

(3) Joint filler. Joint filler shall be preformed sponge rubber.

(4) Joint sealant. Joint sealant shall be cold applied, multicomponent, and elastomeric. The sealant is installed in joints to prevent weathering of joint filler and is subjected to cyclic tension and compression loading as the temperature changes.

(5) Waterstops. Waterstops should be installed in joints of concrete sections when watertightness is desired. Guidance for use of waterstops is given in EM 1110-2-2102 and EM 1110-2-2502. Waterstops in joints which may experience appreciable movements should be rubber or polyvinyl chloride.

b. Structural design loadings. The forces acting on the structures and the weight of structures should be defined to perform the stability analyses and the design of the reinforced concrete sections of the structures. Some of the applied forces may be indeterminate in nature, and the designer must assume their location, direction, and magnitude. Assumptions should be based on available criteria, loading conditions, and the application of engineering expertise and judgment. Unsymmetrical loading, resisted by sliding friction or passive pressure, should be analyzed.

(1) Earth pressures. Earth pressures on walls of rectangular channels should be determined by using the criteria given in EM 1110-2-2502 and ETL 1110-2-322 for T-type retaining walls and EM 1110-2-2504 for I-walls. Free-draining granular materials should be used for backfill behind walls to reduce the lateral earth pressure, decrease pressures due to frost action, minimize pressure increases from in situ materials having expansive characteristics, and increase the effectiveness of the drainage system.

(2) Hydrostatic pressures. Hydrostatic horizontal pressure behind walls and uplift pressure under paving slabs should be determined. Uplift pressures should be determined for the steady-state seepage and drawdown conditions. The magnitude of hydrostatic pressures may be reduced by installing drainage systems as discussed in paragraphs 2-4, 3-3, 4-5, and 5-4.

(3) Earthquake forces. Seismic forces for vertical walls of rectangular channels may be significant and should be determined using criteria given in ER 1110-2-1806 and EM 1110-2-2502. Seismic forces cause only small increases in earth and hydrostatic pressures on paving slabs and should be ignored.

(4) Wind. Reference should be made to EM 1110-2-2502 for wind loads on walls but these are usually negligible. Wind loads on paving slabs should be ignored.

(5) Surcharge. Surcharge loads from construction, operations and maintenance equipment, and highway or street vehicles should be included as appropriate. Criteria for determining surcharge loads are given in EM 1110-2-2502.

c. Constructibility. The dimensions of the concrete structures of flood control channels should be such that the reinforcement, embedded metal, and concrete can be properly placed. The thickness of the top of walls greater than 8 ft in height and footings supporting such walls shall not be less than 12 in. to facilitate concrete placement. The thickness of the top of walls less than 8 ft in height and containing only one layer of reinforcement may be decreased to 8 in. Walls should be designed for construction simplicity and maximum reuse of concrete forms. Dimensions of monoliths, independently stable units of concrete structures, should be selected to allow practical volumes of concrete placements.

d. Joints in concrete. Joints are provided in the reinforced concrete structures of flood control channels to divide them into convenient working units and to allow for expansion and contraction. The number of joints should be kept to a minimum to reduce construction and maintenance costs. There are no exact rules for determining the number and location of joints required in structures. The structural design requirements, overall dimensions, and form requirements should be considered to efficiently locate the joints. Guidance on expansion and contraction joints of retaining walls is given in EM 1110-2-2502. The location of all joints should be shown in the drawings.

(1) Construction joints. Construction joints are used to divide structures into convenient working units and to provide bonded joints where concrete pours have been terminated. Keys are not recommended for horizontal construction joints because they are difficult to construct of sound concrete and to adequately clean for good bonding. Reinforcement should be continuous through construction joints.

(2) Contraction joints. Contraction joints are used to divide structures into independently stable, constructible monoliths to control cracking due to curing, shrinkage, and temperature differentials. The spacing of contraction joints is dependent upon the characteristics of foundation materials, climatic conditions, channel flow patterns, and other geophysical site conditions. Reinforcement should not be continuous through contraction joints.

(3) Expansion joints. Expansion joints are used to prevent crushing or spalling of concrete at abutting surfaces due to thermal expansion or differential movement resulting from settlement or applied loads. Expansion joints are commonly located at changes or junctures in structures. Reinforcement should not be continuous through expansion joints.

2-4. Drainage Provisions

Drainage systems should be provided to control excessive hydrostatic pressures acting on the concrete structures of lined flood control channels where the permanent water table is above the channel invert. These systems should also be provided where the temporary water table is expected to be above the channel invert due to local ponding or seasonal variations.

a. Drainage systems. Drainage systems used in past designs include open, closed, and weep-hole systems. Open drainage systems consist of collector drains which drain through weep holes in the channel lining. The collector drains are encased with a graded filter to prevent blockage of the drain or removal of the foundation material. Closed drainage systems consist of drainage blankets, collector drains, collector manholes, and outlet drains which drain into the channels. The outlet drains are provided with check valves to prevent the backflow of water from the channels into the drainage system. Weep-hole systems have been used for paving on rock foundations and usually consist of a system of holes drilled in the rock and weep holes in the paving slab. These systems are subject to clogging and require routine maintenance. Channel water will tend to backflow into the system and deposit silt during high channel water levels. Open systems are obviously more susceptible to clogging because they do not restrict backflow and should only be used for noncritical channels, side channels, and small channels (about 3 m (l0 ft) maximum in bottom width and depth, respectively). Closed systems shall be used for critical and large channels of which the continuous relief of hydrostatic pressures is critical to channel performance.

b. System selection. The investigations, analyses, and conclusions made in the selection of a drainage system for a flood control channel should be thoroughly documented in the project design memorandum. This documentation should include, but not be limited to, analyses of the geological and geohydrological investigation data, suitability of the system type for the specific site, and suitability of the system type for the operational requirements.

c. System design investigation. Design of a drainage system requires information on subsurface soils and/or rock and ground water conditions along the channel area and also information on the characteristics of streamflow. A general understanding of the geology and geohydrology of the area should be obtained. Specific project data include information on the extent, thickness, stratification, and permeability of subsurface materials along the channel and information on ground water levels, their variations, and the factors which influence the variations. Information is also needed on stream stage variations and related ground water fluctuations so that the design differential head condition can be developed.

d. System design. The design of a drainage system should be based on the results of seepage analyses performed to determine the required discharge capacity of the system. The design includes determination of the drainage blanket permeability and thickness requirements, collector drain spacing and size, and manhole spacing and location. Appendix C provides example seepage analyses and drainage system designs. Contract plans and specifications should require modification of the drainage system to alleviate perched water conditions encountered during construction. Drainage systems for trapezoidal channels are described in paragraph 3-3 and illustrated in Plate 1. Drainage systems for rectangular channels are described in paragraphs 4-5 and 5-4 and illustrated in Plate 2.

e. System effectiveness. As discussed in paragraph 2-4*a*, drainage systems require routine cleaning and maintenance to relieve clogging. The need for routine operation and maintenance activities such as the control of aquatic weeds and silt removal should be addressed in the design. Experience has shown that many local flood protection projects are not adequately maintained. Therefore, unrelieved clogging can be expected to occur, thereby decreasing the effectiveness of the systems and resulting in increased hydrostatic pressures. Presently, precise information on the extent of loss of effectiveness of drainage systems during the life of projects is not available. However, since it is known that some loss of effectiveness does occur, channel lining designs should reflect possible increased hydrostatic pressures resulting from some loss in effectiveness of the drainage system during the life of the project. Without supporting data, drains may be assumed to be 75 percent effective. The criteria used in the design for determining the extent of loss of drainage system effectiveness should be thoroughly documented.

2-5. Vehicular Access Ramps

Vehicle access ramps are provided to permit vehicular access during the construction and maintenance of projects. These ramps should enter the channel from an upstream to downstream direction. The number of ramps should be held to a minimum and each ramp carefully located so that its effect on the hydraulic efficiency and flood surface profile is minimized.

2-6. Control of Water During Construction

The channel flows which should be controlled during construction are primarily local runoff and a selected storm runoff. This flow must be controlled by diversion, pumping, or phasing of the construction. One side of the channel is often constructed while providing for diversion of the water on the other side of the channel. After completion of the first side of the channel, flows are diverted to the completed side while completing the opposite side. Contract plans and specifications shall define the level of flood protection for which the construction contractor is responsible. The contractor should be responsible for the means of controlling the water, subject to approval by the government contracting officer.

2-7. Maintenance During Operation

Proper maintenance of flood control channels is essential to satisfactory performance. This requires periodic inspection of the channels, including the concrete linings, appurtenant concrete structures, and the subdrainage system. Current Corps Operations & Maintenance (O&M) provisions require that flood control projects be inspected periodically. The frequency of project inspections and other operation and maintenance requirements shall be identified in the project O&M Manual. Any deficiencies critical to the function of the project should be corrected with urgency. Broken concrete and cracks in the concrete which are wide enough to cause concern should be repaired. Subdrain systems that are clogged shall be cleaned.

2-8. Protection of Private Property

Certain reaches of the channels often require protection or underpinning of private property during channel construction. Shoring concepts often include drilled tangent pier walls or steel H-pile (soldier pile) walls with lagging. The wall system must control lateral deflections and prevent loss of ground. These wall systems are sometimes designed with anchor ties or struts. Other less expensive methods of shoring may be acceptable, depending upon the closeness and criticality of the property to be protected. The effects of construction vibrations and the removal or loss of lateral resistances should be evaluated. The effects of construction vibrations may be evaluated using the criteria developed by Woods and Jedele (1985) in Appendix A.